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Heterogeneous Cenozoic cooling of central Britain: insights into the complex evolution of the North Atlantic passive margin

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The western flank of the North Atlantic passive margin has experienced multiple episodes of rock uplift and denudation during the Cenozoic that have been locally variable in scale. Two regional scale exhumation events have been identified: early Palaeogene and Neogene [see 1 for review]. The former has been identified both onshore and offshore and it appears to be temporally coincident with basaltic magmatism related to the arrival of the proto-Iceland mantle plume beneath thinned continental lithosphere, which may have cause long wavelength, low amplitude dynamic uplift. Quantifying the amount of early Palaeogene exhumation using mineral thermochronometers may be complicated by elevated heat flow. The magnitude and timing of exhumation during the Neogene is even less clear, as is the driving mechanism. Quantifying the amount of early Palaeogene exhumation, determining the precise timing as well as the amount of uplift and erosion in the Neogene, require detailed application of low temperature thermochronometers.

Here we present the first multiple low temperature thermochronometer study from S Scotland, N England and N Wales. New apatite fission track (AFT) data are integrated with apatite and zircon (U-Th-Sm)/He (AHe and ZHe, respectively) ages to establish regional rock cooling history from 200°C to 30°C. To precisely constrain the early Palaeogene cooling history, and to better define the possible Neogene cooling event, >20 single grain AHe ages have been produced on key samples and modelled using the newly codified HelFrag technique. The new AFT and AHe ages confirm earlier studies that show the Lake District and North Pennines experienced rapid cooling from >120°C in the Palaeogene. The amount of cooling/exhumation gradually decreases northwards into S Scotland and southwards in N Wales; there is no evidence for the rapid Palaeogene event in areas ∼70 km from the Lake District centre. Inverse modelling of the AHe and AFT data suggest that the rapid cooling episode started at ∼60 Ma, and was finished by 30 Ma; possible causes are either mantle driven uplift (62-58 Ma) or rebound caused by break up during opening of the North Atlantic Ocean (56-53 Ma). The high Palaeogene palaeotemperatures may be related to the elevated heat flow due to magmatic underplating and the presence of radiogenic granite batholiths covered by low-conductive sediments. ZHe ages from a borehole in the North Pennines constrain the Palaeogene geothermal gradient to ∼70°C/km. If the same value is applied regionally, only 1.2-1.7 km were removed during the Palaeogene in the Lake District. Most thermal histories suggest that the region had cooled to less than 30°C by the end of the Palaeogene. This implies that less than 1 km was removed during the Neogene, suggesting that, if a rapid denudational event existed, was of minor entity, probably reshaping the Palaeogene landscape.

The thermochronometric data constrain the Palaeogene event within an area with wavelength <150 km and an amplitude of <2 km, suggesting that pre-existing geological structures, lithology and rheology of the lithosphere may be a primary control on the landscape response to long wavelength disturbances.

[1] Green P.F., et al. 2012. Proc. Geol. Assoc. 123, 450-463.